Human-Enabled Science

Michael B. Duke
Colorado School of Mines
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Overview

- Humans may accomplish many field scientific investigations better, faster and cheaper (science product/cost) than robots alone.
- Humans must be aided by robots because of environmental constraints; robots have increased performance if humans can be nearby
- Humans and robots working together will be required to expand scientific horizons through the creation of infrastructure

Background

- Apollo Lunar Exploration
  - Demonstration of capability for field observations using simple tools
  - Complex sample collection – cores, rake, hammer
  - Documentation of samples
  - Demonstration of ability to work in the lunar environment
  - Identification of issues that restrict human explorers
- Hubble Space Telescope Repair
  - Complex manipulations allowed enhancement of instrument performance and extended lifetime

Robots vs. Humans as Field Geologists

- Mars Athena Rover – Mars 2007 mission
  - ~200 kg instrumented rover
  - Capable of traversing several kilometers in 180 day mission, making detailed panoramas and crudely analyzing a few samples at three locations
- Apollo Astronaut
  - ~200 kg astronaut and suit
  - Capable of traversing several kilometers in 1 day, making in-situ observations and taking pictures, collecting several kilograms of sample for analysis
- In a variety of comparisons, humans on-site can perform approximately 2 orders of magnitude more rapidly and with better capability than automated rovers, for similar mass delivered to the surface

Robot-Aided Astronauts

- Astronauts are limited in several ways
  - Must avoid hazardous terrain
  - Eyes are not as sensitive as spectrometers
  - Humans tire
- Robots can fill the gaps
  - Robotic field geologists may be expendable (?)
  - Field and laboratory instruments are extensions of human senses
  - Humans can teleoperate rovers without physically tiring; in some cases one human can operate several robots; or robots can be operated from afar

Unique Capabilities of Humans

- Rapid decision-making based on synoptic observations
- Hand-eye coordination
- Abstract thought and communications
- Short term memory aids multitasking and synoptic observations
- Capability to improvise using tools and materials from the environment
- Subject for human life science investigations

An example: Determining the age of a rock

- Rock age determinations require sample preparation and sophisticated mass spectrometric analysis.
- Absolute age determinations of rocks can be critical to understanding the sequence of geological/ biological events
- Typically, isotope chronology requires two separate rock components to be analyzed (eg a phase rich in a radioactive element and one poor in the same element, to serve as a background comparison)
- Concentrates must be separated from rocks containing the required minerals. This can be accomplished on Earth if a knowledgeable scientist has access to sample manipulation capabilities (eg magnetic separation, density separation). However, the conditions of separation vary from rock to rock. Therefore, the separation technique is quite iterative.

An example: Determining the age of a rock

- Once separated, the mineral concentrates are subjected to chemical digestion and processing. This typically requires additional sample manipulation.
- The residue from sample processing must be converted to a form that is compatible with the mass spectrometer, including loading the sample onto the filament of an ion source.
- Once these have been done, mass spectrometry is straight forward and is typically carried out almost entirely by automated systems.
- The bottom line: Absolute chronology of Martian rocks will be done either in laboratories on Earth or laboratories on Mars

Human-Robotic Construction

- Capabilities of robots
  - Repetitive tasks done without tiring
  - May be stronger than humans where required
  - May be more precise than humans where required
- Capabilities of humans
  - Respond rapidly to contingencies
  - Can cope with variable environment
  - Synoptic inspection both before and after assembly operation (is it going to fit? did it fit?)
  - Hand-eye coordination
  - Improvisation of tools
- Disadvantages of humans
  - Sometimes humans are clumsy
  - Sometimes humans make poor decisions under stress
  - Require infrastructure (life support systems, etc.)
  - Potential source of contamination

Humans, Plants and Animals

- Expansion of humans beyond LEO is an important goal of space exploration.
- This will require understanding humans, plants and animals (food) in relevant environments
- Advantages of humans
  - Capable of working in environment that is poorly defined (plants do not always grow the same)
  - Synoptic observation(is a plant problem due to nutrition or insects?)
  - Effectively select and prepare appropriate samples for analysis

A Strategy for Improving Human Exploration Capabilities

- Develop tools that augment human senses
  - Spectrometers, etc.
- Provide tools to augment human strength and diminish fatigue
  - Hand tools, better space suits
- Develop systems that optimize the time needed by humans to do tasks
  - Supervised robotic autonomy, teleoperation
- Develop infrastructure systems that make the environment more transparent to humans
  - Better space suits, space resource development, closed life support systems
- Improve human data integration and communication capabilities
  - Systems to improve team approach to exploration